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Objective Forecasts of Severe Thunderstorms from Observed Surface Predictors

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1. Introduction

An on-going effort at the Techniques Development Laboratory (TDL) aims to develop a useful scheme to forecast the probability of severe local storms 2 to 6 hrs in advance in areas of about 10,000 nm^2. On the basis of experiments to test the predictive value of meteorological parameters based almost solely on hourly surface observations, Charba and Livingston (1973) found important correlations between these parameters and reports of severe weather. The data sample available for that study was too small to support development of useful statistical forecast relationships. Subsequently, data was collected from almost the entire severe storm season of 1973. This report discusses the results found in re-developing the 2→6 hour forecasting equations on the basis of this new data sample. A test of the forecasting skill of these equations was made by applying them to the 1972 data sample.

2. Developmental Procedure

The technique used in this study is based entirely on the classical statistical method (Klein, 1970). An empirical relationship is derived between the weather element to be forecast (the predictand) and various parameters (the predictors) based on data observed at an earlier time. The predictors are extracted from objective analyses of these data. The correlation procedure is designed so that once the empirical relationship is derived, it can have real-time forecasting application given the routine measurements.

event is defined as one or a combination of the following: tornado, funnel cloud, hail $\geq$ 3/4 in. dia., or wind gust $\geq$ 50 kts. In order to get a high enough frequency of storm events, it was necessary to integrate reports over some area and over some time span. The predictand then takes on a value of one if one or more severe weather reports are found and zero otherwise.

In order for the derived relationship between the predictand and predictors to have forecasting value, the area searched and the time period spanned by the predictand was taken downstream in space and later in time from the predictor point. On the basis of many experiments Charba and Livingston (1973) found that the predictor-predictand configuration giving the highest correlations is as shown in Fig. 2.

c. Sample Generation

During the 1973 season we collected data for all days between 28 March and 15 September. Predictor-predictand data were generated at 3-hourly times except at 06 and 09 GMT (Severe weather occurrences are relatively scarce following these times of the day). The statistics within the irregular area covering much of the eastern U.S. in Fig. 1 were archived for regression analysis. However, experiments run on the 1972 sample showed the correlations to be higher when the pooling of data was limited to the 15 x 15 grid area outlined in Fig. 1. Likewise results were improved when the combined spring and summer days were separated.

d. Screening Regression

The screening regression procedure (Miller, 1958) yields equations of the type

$$y = a_o + a_i x_i \quad i = 1, 2, 3, \ldots, N \qquad (1)$$

b. Dependent Data Test

Results of an application of the 21 GMT equation to the developmental data is shown in Table 3. We find as the probability, P, increases from 0 to 50% and above, the severe weather frequency, n_s, increases monotonically from 1.6% to over 70%. Over 50% of all severe weather events are coupled with probabilities of 20% and above.

c. Independent Data Test

As expected some deterioration in the results was found when the 21 GMT equation was applied to the independent 1972 data sample. For instance, the RV for the independent data was 13.5% as compared to 16.0% for the dependent data. Note also that a greater percentage of the forecasts (F) fell into low categories while fewer forecasts reached the upper categories.

We should point out that the independent sample has some weaknesses which may have contributed to the relatively low variance reduction. For one thing, it's too small--only 16 days worth. This could have had some impact particularly since far from all severe weather occurrences are reported. Another problem is that the times involved in the independent sample were one hour earlier than 21 GMT.

d. Comparison with Operational Forecasting Systems

Currently, in the National Weather Service, there are no automated forecasting systems for severe thunderstorms for projection times less than 12 hrs in advance. There are, however, such systems making forecasts of 12 → 24 hrs (David, 1973) and 24 hrs only (Reap, 1974). These schemes are similar; they are both based on the screening regression approach and both use numerical forecasts from NMC's numerical prediction models as input. David's equation also uses 6-hour old surface observations.

5. Acknowledgments

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6. References

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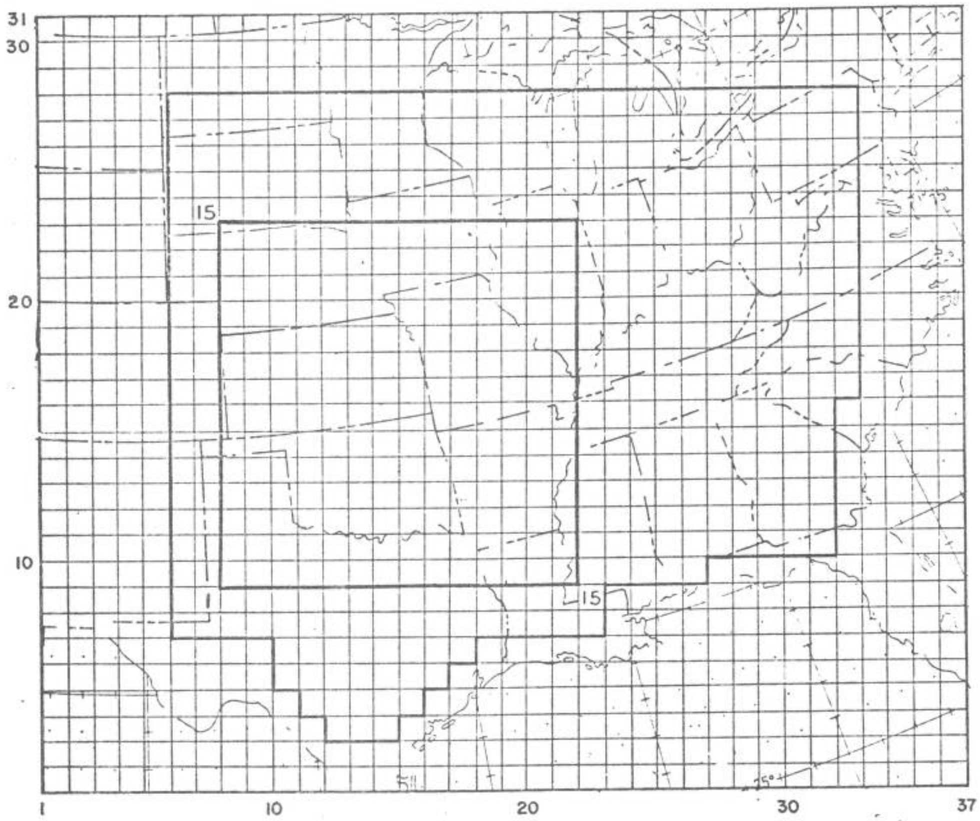

Fig. 1. Analysis grid array; grid spacing averages about 40 nm. The large area outlined by the heavy line denotes the region where predictors were archived. The inner rectangular area, i.e., 15 x 15 array of points, denotes the region where the grid-point data was pooled for the regression runs discussed in section 3.

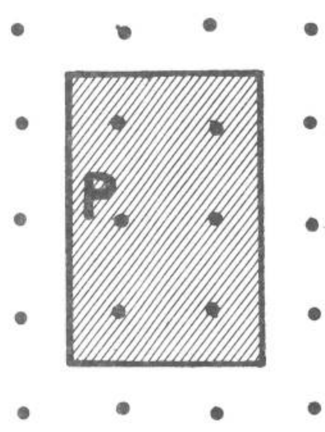

Fig. 2. Predictor-predictand configuration. The array of points represents a blown-up view of a small subset of grid points in Fig. 1. The predictors at a grid point, gridpoint P for example, are correlated with reports of severe weather occurrences in the stippled area (80 x 120 nm^2) occurring 2-to 6 hrs later than the predictor time. Predictors at each of the adjacent points are paired with a corresponding predictand "box".

Table 2. Spring season regression equation for forecasting severe weather occurrences during the period 2300 → 0300 GMT from predictors at 2100 GMT. (Local time-change predictors use data observed 3 hrs earlier). The developmental sample included 71 spring days of 1973; combining the statistics within the 15 x 15 array in Fig. 1 for the regression runs gave a total of 15975 cases. Listed below is the order of predictors selected, the coefficient of each predictor, and the reduction (or explained) variance (RV) of the predictand with each predictor added to the equation.

Predictor (Units)	Coefficient	RV (%)
	constant - 3.338	
1. $\nabla.q\vec{V}$ (g/kg. sec)	$- 2.539 \times 10^{2}$	7.94
2. q (g/kg)	6.976×10^{-3}	11.36
3. $\Theta_E \lvert \nabla\Theta_E \rvert$ (C^2/km)	2.352×10^{-2}	12.48
4. $\nabla.\vec{V}$ (sec^{-1})	5.038×10^{3}	13.27
5. P (mb)	$- 3.215 \times 10^{-3}$	14.25
6. T (C)	$- 6.557 \times 10^{-3}$	14.71
7. S (C)	$- 6.626 \times 10^{-3}$	15.28
8. $\frac{\partial p}{\partial t}$ (mb/hr)	$- 3.458 \times 10^{-2}$	15.69
9. $\nabla.\Theta_E\vec{V}$ (C/sec)	$- 9.970 \times 10^{1}$	16.03